Development of different kind of IFU prototypes for the OPTIMOS-EVE study for the E-ELT

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ABSTRACT

The OPTIMOS-EVE concept provides optical to near-infrared (370-1700 nm) spectroscopy, with three spectral resolution (5000, 15000 and 30000), with high simultaneous multiplex (at least 200). The optical fibre links are distributed in four kinds of bundles: several hundreds of mono-object systems with three types of bundles, fibre size being used to adapt spectral resolution and 30 deployable medium IFUs (about 2”x3”). We are optimising the design of deployable IFUs to warrant sky subtraction for the faintest extragalactic sources.

This paper gives the design and results of the prototype for the high resolution mode and the preliminary design of a medium IFU developed in collaboration between the GEPI and the LNA.

Keywords: OPTIMOS-EVE, E-ELT, IFU, Optical Fibre

1 INTRODUCTION

OPTIMOS-EVE is able to address a major fraction of the E-ELT science cases, from extra-solar planets, stellar populations beyond the Local Group, properties of dark haloes, the intergalactic medium, up to the most distant galaxies accessible with the E-ELT.
Spectroscopy over the wavelength region available from the ground, from the UV to the non-thermal infrared, has been, and will remain a key technique to investigate virtually all types of astrophysical targets. At z=0 most of the spectral lines, fundamental for deriving astrophysical information, are found in the UV-optical range. OPTIMOS-EVE offers low, medium and high resolution spectroscopy (R ~ 5,000 – 30,000) from the ultraviolet to the near-infrared, for multi-object studies of sources nearby and at cosmological distances.

The instrument consists of three main sub-systems: a pick-and-place positioner, fibre bundles for various spectral resolutions and integral field units and two highly efficient VIS-NIR spectrographs with VPH gratins working in 1st order.

The fibre system was designed by the GEPI at Observatoire de Paris.

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2 DESCRIPTION

A schematic view of this system is shown in Figure 1. It is designed to fit within the volume and mass limits of the focal plane station.

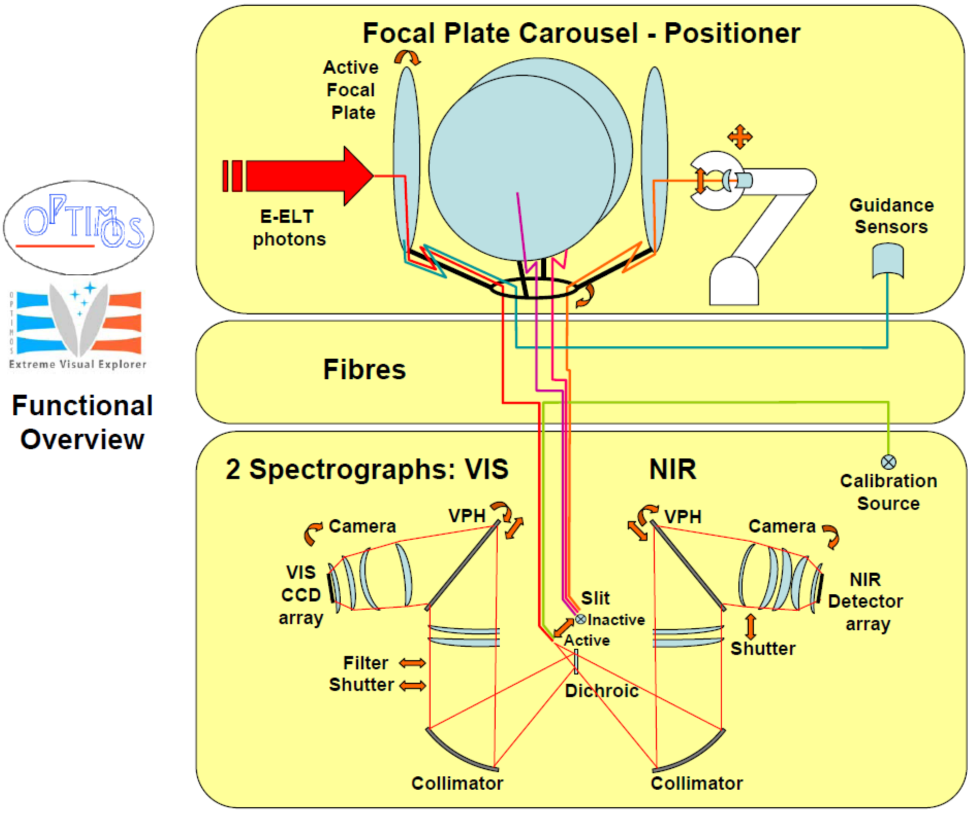

Figure 1 Schematic overview of OPTIMOS-EVE

The OPTIMOS-EVE fibre system ensures the link between the spectrographs and the positioner. This fibre system will be composed of four kinds of links: 3 types of Mono-Object (MO) and 1 type of Medium-IFU (MI). For these four modes, the optical aperture conversions at the input end on the bundle are realized by a coupling with a microlens. The pupil of the telescope is imaged on the fibre core.

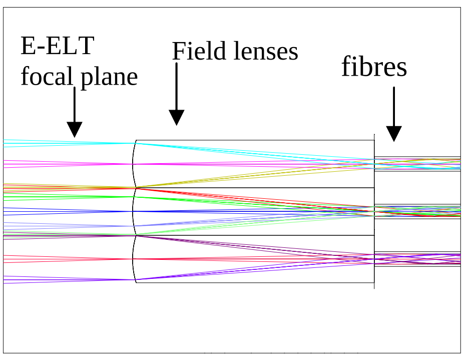

Figure 2 Fibre injection principle (pupil image on fibre core)

The MO field of view is 0.9'' for Low and Medium Resolution (LR and MR) and 0.81'' in High Resolution (HR). The Integral fiel Unit MI have 0.3'' spatial sampling on sky and operate in Low Resolution (LR) only.
At the output of the bundle the fibres of one type of fibre buttons, are arranged into two pseudo slits, feeding the spectrographs. For the output no microlenses are required since the spectrograph collects an aperture of f/3.5.

3 MO-HR FIBRE PROTOTYPE

We aim to demonstrate the feasibility of the HR button, because of the criticality of the assembly of fibres with diameter smaller than 100 µm.

The prototype is been made up of 52 fibres 70/84/95µm (FBP Polymicro). At the input, the fibres are glued into a hole array that respects the pitch the microlenses array which be glued on the fibres. The drilling of these holes of nearly under 100µm should be accurate at ±5µm. This piece has been made in house, at the workshop of the GEPI.

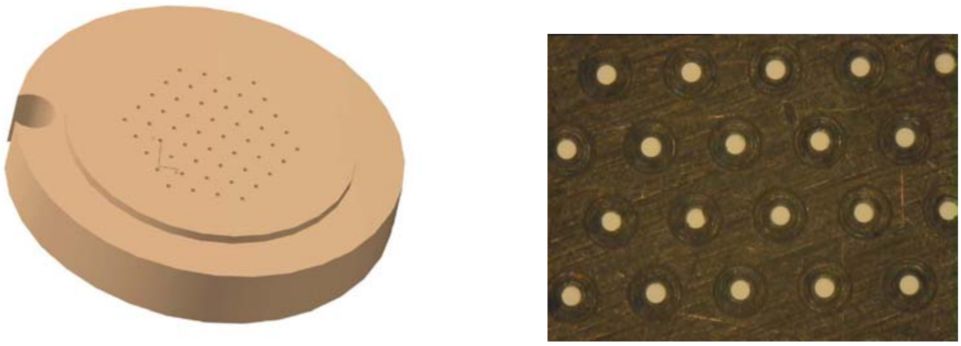

Figure 3 Design of the holes arrays

At the exit, the fibres are glued closer to each other into a groove. The company SEDI, in France, has made the cabling, assembling, gluing the two ends of the 52 fibres and the polishing of the two tips.

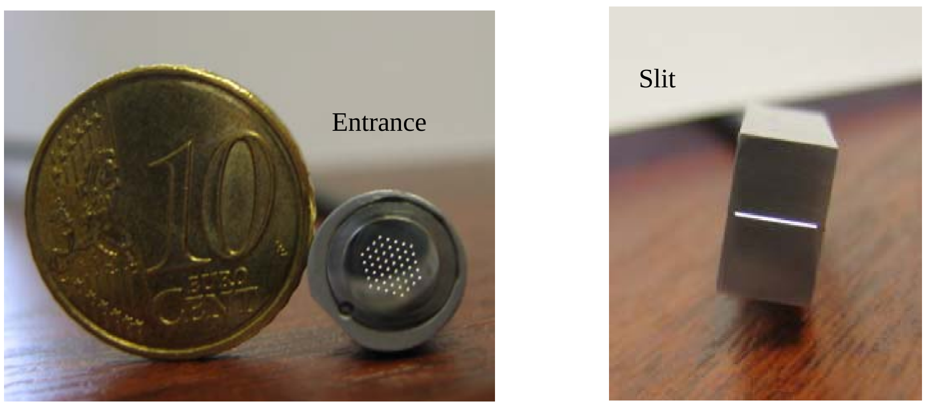

Figure 4 Gluing of the fibres into the tips

SEDI glued also the microlenses array from AMS (Advanced Microoptic Systems, in Germany) in order to prepare and optimise the process of gluing the huge number of fibre links for OPTIMOS-EVE. The specifications of the microlens array are respected and the alignment between the fibres and the microlenses is perfect. This good result is illustrated on the picture on the right of Figure 5 with the fibres retro-illuminated.

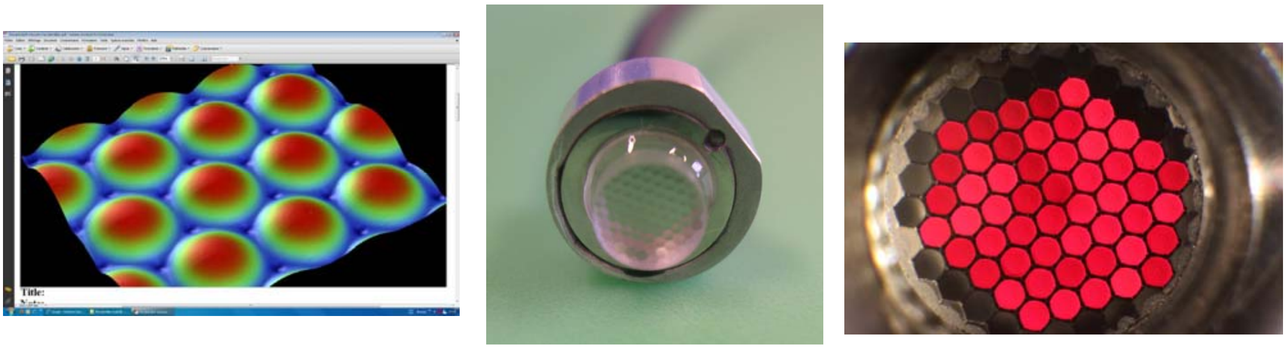

Figure 5 Gluing of the microlenses array

4 DESIGN OF DEPLOYABLE IFUS

Thirty Medium IFUs can be positioned anywhere over the 10 arcminute field of view. The 30 Medium-IFUs (MI-LR) consist each of 52 target fibres (each 0.3" in diameter) and 4 outlying sky fibres, at a fixed position with respect to the science fibres, in an arrangement shown below. The total sky coverage per MI-LR is 1.8"x3".

The arrangement of the fibre bundles into the spectrographs is again similar as for the MO buttons. A pseudo slit is made out of the fibres in subslits, 10 of which are equipped with an additional calibration fibre.

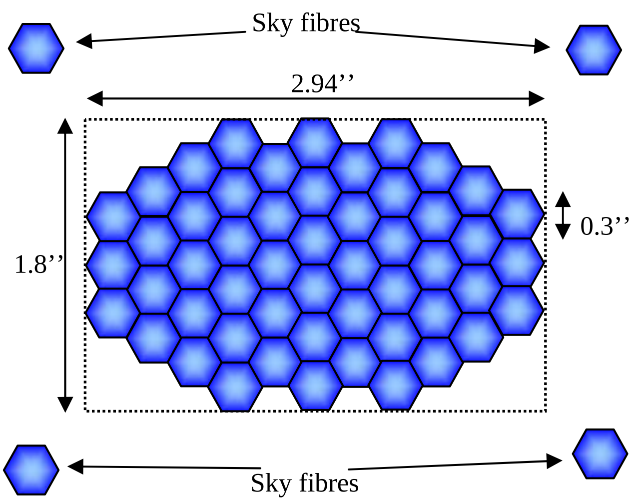

Figure 6 IFU design

A new prototype will be made in collaboration with the LNA with the technique of the mask instead of the mechanical piece at the ends.

4.1 Fibre positioning array

To ensure maximum throughput it is important that the microlens array is accurately registered with the two-dimensional array of optical fibres. Individual positioning is very time consuming for a large number of fibres and positioning errors are not entirely eliminated. Another approach is to use an array of hexagonally close packed steel tubes (Haynes et al. 1999, Murray et al. 2000). An RMS positioning error of 6 µm can be obtained with this technique but the choice of the pitch is limited by the size of tubing available. A different approach was adopted for Eucalyptus IFU, with the fibres positioned in array of accurately drilled holes as illustrated schematically in Fig. 7.

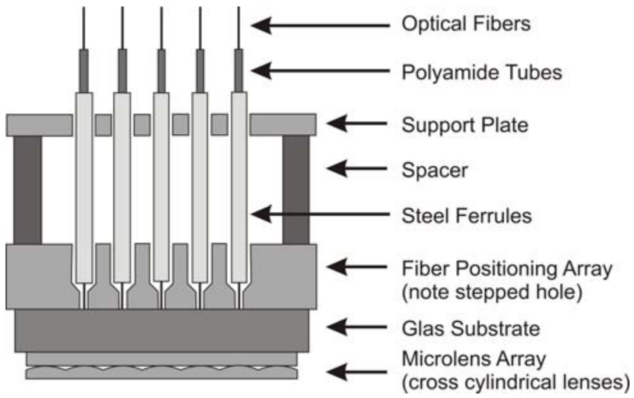

Figure 7 *Schematic of the SPIRAL microlens array concept and fibre-positioning array.*

In this case, the fibre-positioning array is basically a grid of holes spaced with a specific pitch. The holes are machined using custom made drills with different diameters. This produces a stepped hole, with the smaller diameter hole used for fibre positioning while the larger hole is used to accommodate a steel ferrule. The small holes are approximately 10 μm larger than the fibre diameter to allow sufficient space for a glue to penetrate. Using a stepped hole also allows a greater depth of material to be machined than by using a small drill alone. This permits a thicker, hence more robust, piece of material to be used. Both, the hole array and support plate are made with toolmakers brass. To secure the fibres, ferrules, and tubes in place the whole input assembly is immersed in a container of EPOTEK 301-2 adhesive. This epoxy is chosen due to its excellent wicking properties and low shrinkage upon curing. After curing, which takes approximately three days at room temperature; any excess of glue is removed prior to optical polishing before the attachment of the microlens array.

In general, the schematic shown in Fig. 8 is the base of the entrance device of the lenslet IFU system. This device is much easier to be manufactured than the device used in SPIRAL and Eucalyptus. In fact, this new version does not require any precision in the holes confection on the composite plates. To obtain precision with the fibres position we have used a third plate called mask of precision, Fig. 9. This is a metal mask very thin obtained by a technique called electro formation. The mask obtained by this way may be configured to have holes with specifics diameters and pits, with error around 1 micron in the diameter and in the position of the holes. This technique may produce a metal nickel plate with 200 microns of thickness and the procedure is very cheap. Taking in account these facilities; the mask will define the precision of the fibres array.

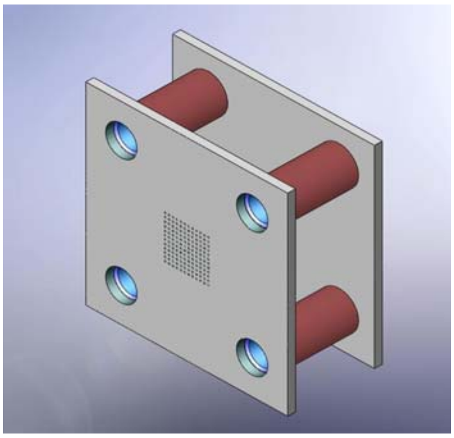

Figure 8 *Schematic of the composite plates set to build the entrance device of lenslet IFU.*

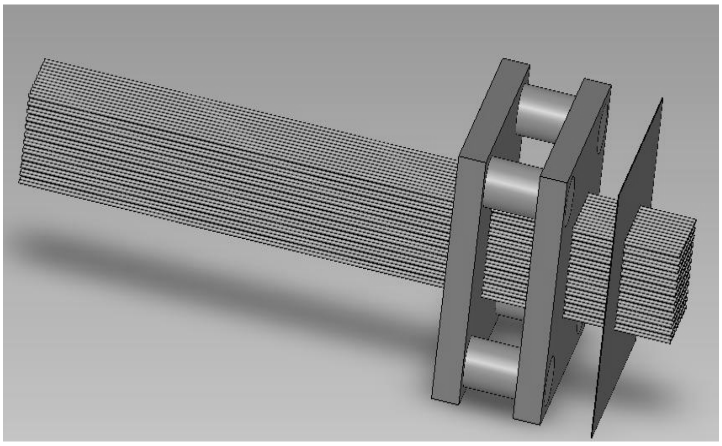

Figure 9 *Entrance device during the assembling step, where the matrixes of holes in the composite plate set and in the precision mask are populated with the optical fibres terminations.*

It is possible to obtain micro holes with the diameter exactly one or two microns larger than the diameter of the fibre used. For another hand, the diameter of the holes in the composite plates does not need to have any precision and may be much larger than the diameter of the fibre. Since that, the step holes with different diameters in the composite plates it is not more necessary, also will be not necessary to use ferrules and any kind of protection to the fibres. Eventually a device like as shown in the Fig. 8 need to be made under a microscope because the diameter of the fibre may be much small and the number of fibres involved at the assemble may be high. However, after assembled, the precision mask is glued against the composite plate and all set is immersed in EPOTEK 301-2 following the old procedure. To obtain the maximum throughput the surface of the fibres should be polished such that they are optically flat and free from scratches. The pre-polishing process starts with the removal of excess glue with 2000 grit emery paper. Initial lapping with 6 μm diamond slurry on a copper plate and a second lapping with 1 μm diamond slurry on a tin-lead plate is used until the complete removal of the precision mask. Without the metal mask, the material of the composite plate is self-abrasive enough to produce a polishing of high performance of the optical fibres on a chemical cloth. This procedure defines the condition to attach the microlens array against the composite plate of fibre terminations as a shown in the Figs. 10 and 11.

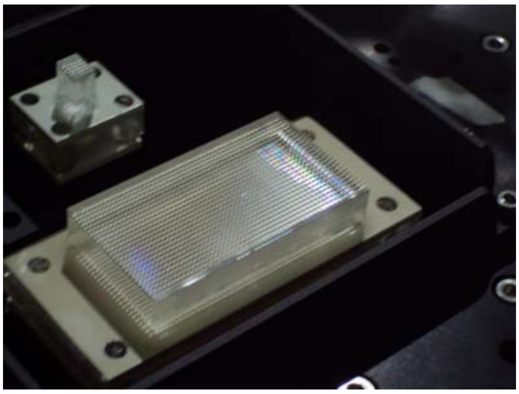

Figure10 *Microlens array of SIFs IFU after to be alignment and attaching by UV epoxy, against the composite plate with the fibres terminations*

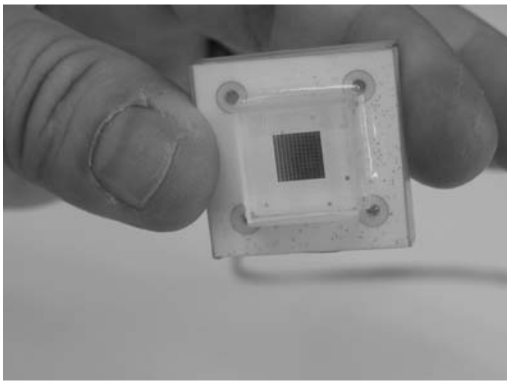

Figure 11 *Complete input device, fibres array and microlens array, of FRODO spec IFU. Photograph obtained after dried the UV epoxy.*

4.2 Fibre slit device

The best option to construct a slit device is also to use to use a mask of precision like that described in the anterior section. The device assembled with the correct gap may be made with two twin masks as a shown in Fig. 12. The device is immersed in a container with EPOTEK 301-2. This container is constructed using plates of PTFE doped with graphite to be easily removed after the cure of the epoxy. After dry it is very easy to remove the plates without offer any damage to the block or the fibres. The polishing process consists of: cutting the end of the block and removal of excess glue with 1500 and 2000 grit emery paper; initial lapping with 6 μm diamond slurry on a copper plate and a second lapping with 1 μm diamond slurry on a tin-lead plate is used until the complete removal of the frontal mask of precision. The final polishing may be made with colloidal silica solution on a chemical cloth.

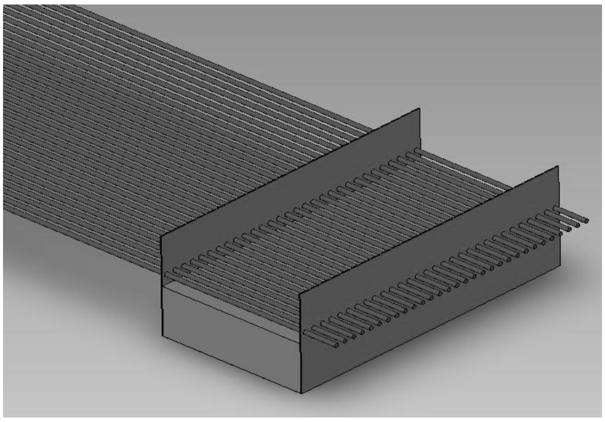

Figure 12 *Schematic of the device used to obtain the slit with correct distribution and gap between the optical fibres. The fibres do not touch the base made with composite.*

5 CONCLUSION

The optical fibre system for the OPTIMOS-EVE study has been designed by GEPI at Observatoire de Paris. Brazil has just joined the consortium and we will collaborate on the fibre aspects through the IFU prototype.

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